COMPARATIVE EVALUATION OF VARIOUS GPS-FREE LOCALIZATION ALGORITHM FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless Sensor Networks (WSN) are tremendously being used in different environments to perform various monitoring tasks such as search, rescue, disaster relief, target tracking and a number of tasks in smart environments. For example wireless sensors nodes can be designed to detect the ground vibrations generated by silent footsteps of a burglar and trigger an alarm. In many difficult and complex tasks, node localization is very important and critical step to fulfill the purpose of WSN. This project was conducted on the basis of localization of sensor nodes in the scope of GPS-free localizations schemes. We firstly investigated the current localization techniques in wireless scenario for the aim of designing a GPS-free localization scheme based on the local coordinate system formation. A multidimensional scaling method based on dynamic curvilinear belt structure and cooperative localization method was used in this project. Then a simulation result and comparison were carried in MATLAB. The vast majority of current materials on spot discovery in WSNs reflect some beacon nodes with known place. Their spots are then used to look for the positions connected with other normal sensor nodes. Manual rating and configuration means of obtaining spot don't scale and are also error-prone, and equipping sensors with GPS is normally expensive and rule isn't followed in indoor and urban environment. As such, sensor sites can therefore gain from a self- setting up method where nodes cooperate with each other, estimate nearby distances on their neighbors, and converge to some consistent organize system containing only translation freedom.

ABSTRAK

Rangkaian Sensor Tanpa Wayar (WSN) yang pesat digunakan dalam persekitaran yang berbeza untuk melaksanakan pelbagai tugas pemantauan seperti carian, menyelamat, bantuan bencana, pengesanan sasaran dan beberapa tugas dalam persekitaran yang pintar. Sebagai contoh sensor wayarles nod boleh direka untuk mengesan getaran tanah yang dihasilkan oleh jejak langkah senyap daripada pencuri dan mencetuskan penggera. Dalam banyak tugas-tugas yang sukar dan kompleks, nod penyetempatan adalah langkah yang sangat penting dan kritikal untuk memenuhi tujuan WSN. Projek ini telah dijalankan atas dasar penyetempatan nod sensor dalam skop localizations skim GPS bebas. Kami pertama menyiasat teknik penyetempatan semasa dalam senario wayarles untuk tujuan mereka bentuk skim penyetempatan GPS bebas berdasarkan pembentukan sistem koordinat tempatan. Kaedah scaling multidimensi berdasarkan struktur tali pinggang lengkung linear yang dinamik dan kaedah penyetempatan koperasi telah digunakan dalam projek ini. Kemudian hasil simulasi dan perbandingan telah dilakukan dalam MATLAB. Sebahagian besar bahan semasa mengenai penemuan tempat di WSNs mencerminkan beberapa nod beacon dengan tempat tinggal. Tempat mereka kemudiannya digunakan untuk mencari jawatan yang berkaitan dengan lain nod sensor biasa. Kedudukan dan konfigurasi manual cara untuk memperoleh tempat tidak skala dan juga kesilapan yang sering dilanda, dan melengkapkan dengan sensor GPS biasanya mahal dan peraturan tidak diikuti dalam persekitaran dalaman dan luar bandar. Oleh itu, laman sensor dengan itu boleh mendapat manfaat daripada diri yang menyediakan kaedah di mana nod bekerjasama dengan satu sama lain, menganggarkan jarak berdekatan jiran mereka, dan berkumpul dengan sistem beberapa konsisten menganjurkan mengandungi kebebasan terjemahan sahaja.

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APS	Ad-Hoc Positioning System
AOA	Angle of Arrival
GPS	Global Positioning System
MSPA	Matrix Transform-Based Self Positioning Algorithm
MDS	Multidimensional Scaling
NLOS	Non-Line-Of-Sight
SPA	Self Positioning Algorithm
RAM	Random-Access Memory
ROM	Read-Only Memory
RSS	Received Signal Strength
RSSI	Received Signal Strength Indicator
TOA	Time-Of-Arrival
TDOA	Time-Difference-Of-Arrival
PDM	Proximity Based Map
WSN	Wireless Sensor Networks

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF PROJECT

Wireless Sensor Networks (WSN) are tremendously being used in different environments to perform various monitoring tasks such as search, rescue, disaster relief, target tracking and a number of tasks in smart environments[28],[41]. For example wireless sensors nodes can be designed to detect the ground vibrations generated by silent footsteps of a burglar and trigger an alarm. In many difficult and complex tasks, node localization is very important and critical step to fulfill the purpose of WSN.

Localization of a node is inherently one of the system parameters. It is evident that node localization is mainly required to report the exact origin and location of events, which will assist the operators or teams to locate the event [2]. Wireless sensor networks (WSNs) can work unattended for long periods, and find a very wide range of applications in the fields of environmental monitoring [12].

Localization in WSN represent the computing of sensor positions in some fixed coordinate system, hence it is of great importance to design an efficient localization algorithm. Localization is one of the fundamental techniques in wireless sensor network. The location estimation methods can be classified into target/source localization and node self-localization [32].

In large scale sensor networks, node localization can assist in routing operation [22], [34]. With a network of thousands of nodes, it is unlikely that the position of each node can be precisely predetermined. Although GPS based localization schemes can be used to determine the node location within a few meters, the cost of GPS devices and the non-availability of GPS signals in confined environments prevent their use in large scale sensor networks [29]. Localization is an important and extensively studied problem in ad-hoc wireless sensor networks. Most schemes require some nodes functioned as anchors with positions configured manually which are error-prone [15], [16].

Positioning all sensors in a sensor network usually consumes a large amount of time and energy. In many applications based on sensor networks, there is no need to estimate the location of all sensors in a sensor network. Sometimes, only sensors within a given direction or region need to be located. [53].

WSNs localization methods can normally be categorized according to three different aspects: (i) the information requirements of the solution schemes: proximity-based localization, range-based localization, angle-based localization and probabilistic-based localization; (ii) the hardware requirements of the solution schemes: absolute localization and relative localization, and (iii) the type of network structure: static network and mobile network.

It is evident that localization in WSN is one of the most fundamental problems since the locations of the sensor nodes are critical to both network operations and most application level tasks. There are a number of GPS-free localization schemes that are available to date.

The algorithm used for GPS-Free Localization for Wireless Sensor Networks can operates asynchronously without a centralized controller; and does not require that the location of the sensors be known a priori. A set of parameter-setting guidelines for the proposed algorithm is derived based on a probability model and the energy requirements are also investigated. A simulation analysis on a specific numerical example is conducted to validate the mathematical analysis [29]. Sensor networks can therefore benefit from a self-configuring method where nodes cooperate with each other, estimate local distances to their neighbors, and converge to a consistent coordinate system which has only translation freedom [16]. The Self Positioning Algorithm (SPA), which is used in distributed mobile wireless networks without GPS receivers, was proposed first by Capkun [7].

Based on the above it is evident that Global Positioning System (GPS) is one of the most popular positioning technologies which is widely accessible and can be deployed for localization WSN, but the weakness of high cost and energy consuming makes it different to install in every node [32]. Therefore, the need to propose a GPS-free localization algorithm becomes more important and necessary for WSN localization.

In this study, the researcher discusses sensor node localization schemes having different features used for different applications and compares the current algorithms used for nodes localization. Different algorithms of localization are used for static sensor nodes and mobile sensor nodes, describing WSNs applications, presenting an overview of localization in WSNs, and finally proposing GPS-free based localization algorithm.

1.2 THE PROBLEM STATEMENT

Most of WSN applications depend mainly on a successful node localization algorithm. In addition to that most of the current literatures on location discovery in WSNs assumes that are some nodes with known position [4], [5], [43]. Their locations are then used to determine the positions of other ordinary sensor nodes.

The localization problem in wireless sensor networks is to determine the location information of all or a subset of sensor nodes, given the measurements of pairwise spatial relationships between the nodes. In the literature, WSNs localization methods can normally be categorized according to three different aspects [36].

Unfortunately, for a large number of sensor nodes, straightforward solution of adding GPS to all nodes in the network is not feasible because of the following [2].

- In the presence of dense forests, mountains or other obstacles that block the line-of-sight from GPS satellites, GPS cannot be implemented.
- The power consumption of GPS will reduce the battery life of the sensor nodes and also reduce the effective lifetime of the entire network.
- In a network with large number of nodes, the production cost factor of GPS is an important issue.
- Sensor nodes are required to be small. But the size of GPS and its antenna increases the sensor node form factor.

For these reasons a better solution of GPS localization algorithm is required and should be cost effective, rapidly deployable and can operate in diverse environments. The need for technological advances in the areas of low energy cost wireless communication embedded computing can solve this problem. However, sensor and integrated circuits make it possible to implement large scale networks with hundreds and even thousands of very small, low-cost, battery-powered, and wirelessly connected sensor and actuator nodes [28].

Environment cost of GPS devices and the non-availability of GPS signals in confined environments prevent their use in large scale sensor networks [15], [32]. In addition to that many algorithms have been proposed to minimize this communication cost. If one node estimates its wrong location, then this error propagates to overall network and further nodes; as a result, wrong information of anchor nodes location is propagated [41]

The researcher concludes that the main disadvantage of GPS-free localization is the communication cost and also the convergence time grow with the increasing number of nodes since each node participates individually in the process of building and merging the local coordinate system.

1.3 THE RESEARCH OBJECTIVES

1. To investigate the existing localization schemes for wireless sensor networks.
2. To propose a GPS-free localization scheme for the local coordinate system formation where nodes cooperate with each other.
3. To evaluate the performance of GPS-Free localization by previous studies and make simulations to measure their performances.

1.4 THE SCOPE STUDY

This study will cover the GPS-free localization of sensor nodes. The study is limited to discuss and design a GPS-free localization scheme based on the local coordinate system formation where nodes cooperate with each other. Two methods will be used in this study; a multidimensional scaling method based on dynamic curvilinear belt structure and

Cooperative Localization method. The study extend the discussion to analyse the existing localization schemes for wireless sensor networks the used algorithm by previous scholars for nodes localization in wireless sensor networks based on local distances estimation of sensor to their neighbors using local coordinate system.

1.5 THE CONTRIBUTION OF THE STUDY

This study will contribute to the body of knowledge in wireless sensor networks in the following aspects:

- The algorithms that will guaranteeing a refinery good accuracy in the sensor localization in GPS-free protocols.

1.6 RESEARCH OVERVIEW

The research is divided into five chapters as follow:

Chapter 1: The introduction of the thesis, which includes the introduction on the topic, the problem statement, the scope study and objectives, and research contribution.

Chapter 2: Presenting the necessary background information and literature review on localization of sensor nodes in WSN and accurate sensor localizations schemes and algorithms in wireless sensor networks.

Chapter 3: The researcher methodology. The researcher proposes the methods and algorithms used accurate distance estimation in WSN.

Chapter 4: The presentation of GPS-free localization technique used in the simulation and evaluation in the study. In the centralized sensor localization algorithm, multidimensional scaling and coordinate alignment techniques are applied to accurately estimate the distance of adjacent sensors.

Chapter 5: The researcher summarizes the contributions of this dissertation on distance estimation for energy efforts in WSN and the advantages of algorithms used for wireless sensor network systems. Then, examining potential extension based on the proposed approaches. Finally, the researcher discusses some directions for future work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the researcher discusses sensor node architecture and its applications, different localization techniques, and the research directions. Localization is one of the key techniques in wireless sensor network.

This chapter will introduce the main concept of localization of sensor nodes in wireless sensor networks and the various GPS-free algorithms for nodes localizations in WSN. In addition to that this chapter will demonstrate the various localization schemes in wireless sensor networks, and compare between the various GPS-free algorithms.

2.2 THE COMPONENTS OF SENSOR NODES

Sensor nodes network consists of software and hardware components. Hardware components are the main part in the network and include radio-transceiver sensors, processors, energy and power unit. The software is the second part of WSN, some of the major software used for administration of nodes are Tinyos, Nano Rk and Contiki, In this section, the researcher demonstrate the hardware components.

1. **Sensors**. There are two types of sensors: analog and digital sensors. Analog sensors deliver data in continuous manner or in a way of analog wave form. The data then is processed by the central processing unit in the administration site that converts he received signal to human readable data form. While the digital sensors

is directly generate human readable data in a digital form. Once the data is processed and converted, then data is sends back to the processor unit for further use by the administrator [14]

2. **Processors.** The microprocessors is one of the main parts of hardware component in WSN and is uses different types of memory in order to process data. The input/output devices and the memory are integrated on the same circuit [27].
3. **Random-access memory (RAM).** The RAM stores the received data from sensors before sending it again, while read-only memory (ROM) is used to store the operating system that run all sensors nodes in the wireless network[45], Most of the time, sensors remain at sleep mode. When the processor is in sleep mode, this does not mean it is not consuming power. In sleep mode, it is involved in other activities like time synchronization [41].
4. **Radio Transceiver.** They are used for receiving and re-transmit the data to other sensor in the wireless network [14] Transceiver uses radio frequency signals. The main purpose of transceiver is to connect the sensor nodes with each other. At this point the wireless sensors consume the greatest energy because of transceiver function. Transceiver has 4 modes in its operation: receiving sleeping, idle state, and sending [27] as shown in Figure 2.1.

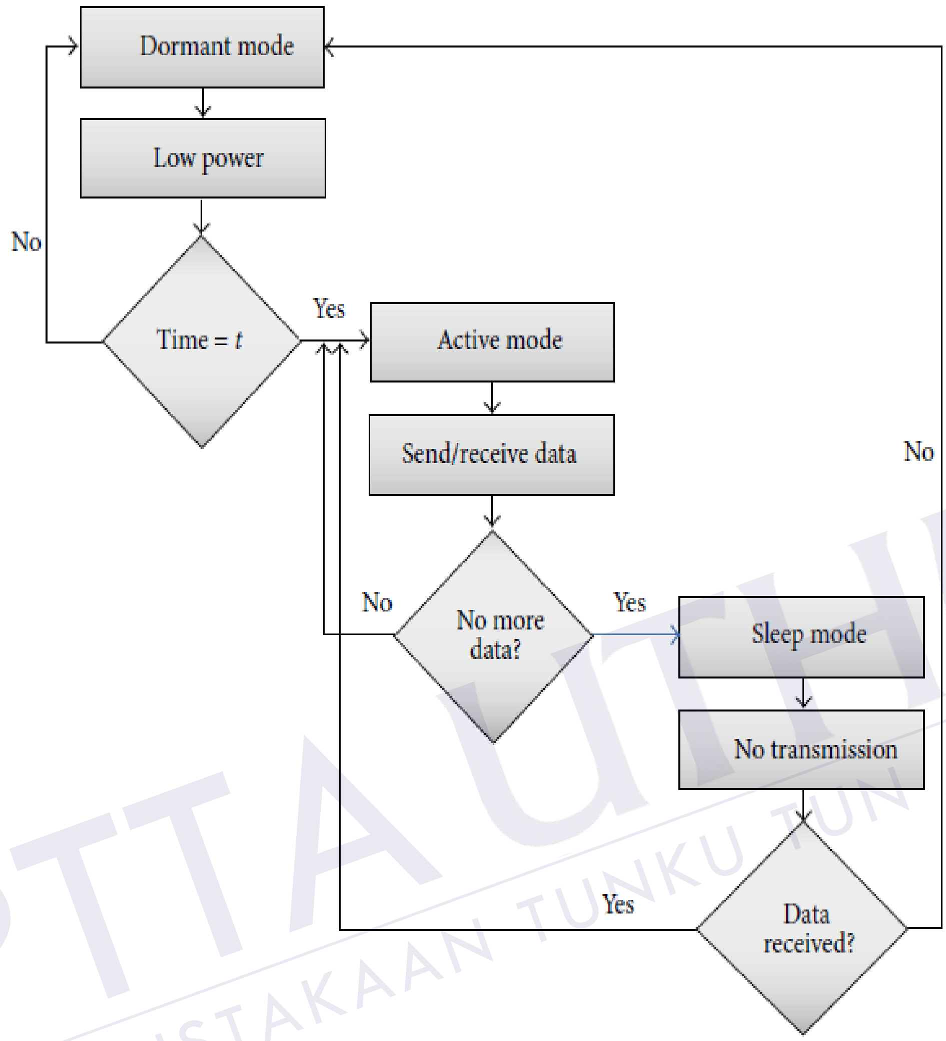

Figure 2.1: Transition of sensor node in different modes [27].

5. **Power Unit.** This is the most important part in wireless sensor network. The sensor node is unable to perform any function without power unit because the receiving and transmitting of signals require power. The power unit determines the lifetime the sensor node, if power dies then the sensor will be stopped and disappears from the network.

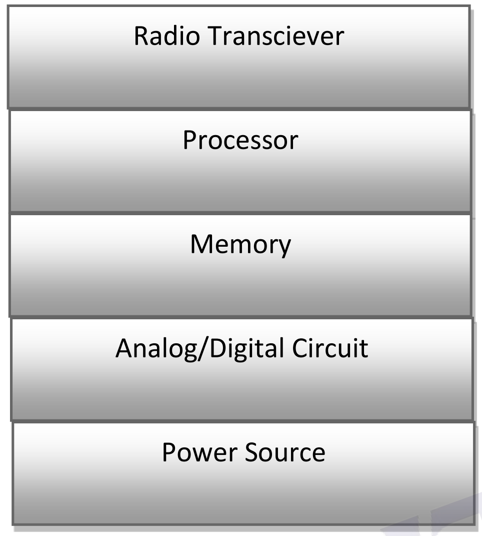

Figure 2.2: Typical architecture of sensor node [41].

2.3 THE FUNCTIONS OF WSN

The main significant function of a wireless sensor network is to collect data and forward these data to certain destination for a specific purpose. Therefore the main thing in this process is to know exactly or estimation about the location of the sensor that collected and send data to the central administration unit. This kind of information is very useful to the operator of the wireless network and can be processed and explained later depending on the application of WSN. According to the using localization technique for sensor nodes is the main task that should be done accurately in WSNs. Most schemes in WSN require some nodes functioned as anchors with positions configured manually which are error-prone [15]. While the Global Positioning System (GPS) is one of the most popular positioning technologies which is widely accessible, the weakness of this technique is mainly in high energy consuming and high cost which makes it different to install in every node and in any location.

It is evident that the main functions of sensor networks include locating, tracking, navigation, and identification of nodes that sending the target signal. The method of sensor networks localization is an important function especially in low sensor-information. As one of the most important functions of sensor networks, object localization and their tracking have attracted many research efforts. Large continuous objects, such as spreading wild fires and bio-chemical spills inside buildings, usually have a coverage far larger than the sensor's sensing range. Identifying the distribution and spatial extent of the large continuous objects and tracking their movement require the collaboration of a large number of sensors. This collaboration involves high communication and complex information processing. Therefore, detection and tracking of the objects represents the most important function of WSN and represent an important research issues in sensor networks.

Based on the above, the researcher concludes that the efforts to reduce energy consumption and cost in GPS localization is unsuccessful and can use only few nodes (beacon nodes) for certain locations in the monitoring area that could be installed with GPS modules. Therefore, it is highly recommended that the rest of nodes localized through GPS-free localization method. The process of finding the location and node position within the wireless network is referred to as node self-localization.

2.4 LOCALIZATION SCHEMES IN WSN

Localization is a technique and algorithm to determine the exact or estimated location of sensor nodes in WSN. Many works and researches have been done in this subject. It is highly enviable to design energy saving method and low-cost technique for localization, anther requirement for efficient localization is the ability to scale the network [41]. Currently there are different localization algorithms are used for static sensor nodes and mobile sensor nodes.

The main measurements used for localization includes: Received Signal Strength (RSS), Time-of-Arrival (TOA), Time-Difference-of-Arrival (TDOA). These mechanisms are differ in term of accuracy and energy consumption as shown in Figures 2.3 and 2.4.

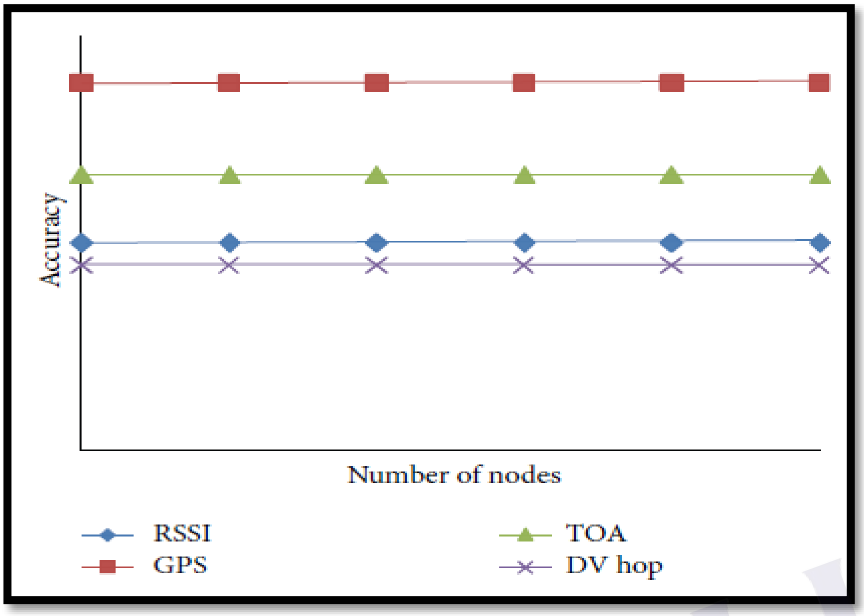

Figure 2.3: Accuracy comparison of different localization [41].

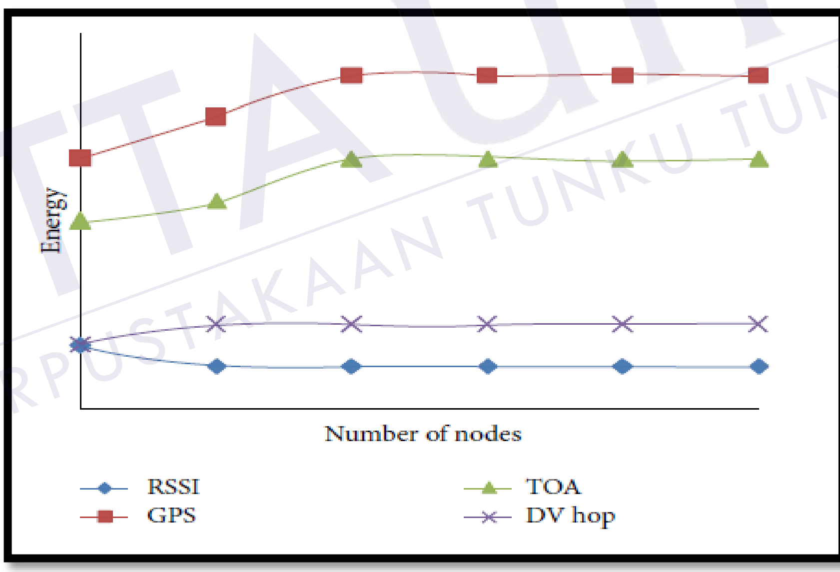

Figure 2.4: Energy efficiency comparison of different localization [41].

The estimation of distance of nodes in wireless sensor network is usually based on radio frequency techniques, which is based on measuring certain parameters of radio signal which is received by one node from other nodes. Some of these parameters are very important for distance estimation such as the angle of arrival (AOA), the time of arrival (TOA), the received signal strength (RSS). Argue that some algorithms depend on angle of arrival (AoA) data [51]. This data is typically gathered using radio or microphone arrays, which allow a listening node to determine the direction of a transmitting node. It is also possible to gather AoA data from optical communication methods. In these methods, several (3-4) spatially separated microphones hear a single transmitted signal. By analysing the phase or time difference between the signal's arrivals at different microphones, it is possible to discover the angle of arrival of the signal. RSS is defined as a voltage measured by a receiver's received signal strength indicator (RSSI) circuit. Often, RSS is equivalently reported as a measured power. Wireless sensor nodes communicate with their neighboring sensor node, so the RSS of the transmitted signals can be measured by each receiver during common communication without presenting additional bandwidth or energy requirements [46]. The RSS method depends mainly on low-cost hardware and only provides coarse-grained distance estimates: by contrast, the TOA and TDoA methods can provide distance estimates with higher accuracies at the cost of extra hardware. Due to cost constraints, it is impractical to equip all sensors in a large-scale sensor network with extra hardware to obtain accurate distance estimates and thus accurate location estimates [53].

Time Difference of Arrival (TDoA) is a commonly used hardware ranging mechanism. In TDoA schemes, each node is equipped with a speaker and a microphone. Some systems use ultrasound while others use audible frequencies. However, the general mathematical technique is independent of particular hardware. In TDoA, the transmitter first sends a radio message. It waits some fixed interval of time, t_{dela}(which might be zero), and then produces a fixed pattern of "chirps" on its speaker.

When listening nodes hear the radio signal, they note the current time, t_{radio} then turn on their microphones. When their microphones detect the chirp pattern, they again note the current time, t_{sound}. Once they have t_{radio} , t_{sound}, and t_{dela} , the listeners can compute the distance d between themselves and the transmitter using the fact that radio waves travel substantially faster than sound in air pulse followed by an acoustic pulse. By determining the time difference between the arrivals of the two pulses, sensor B can estimate its distance from A [19] as shown in Figure 2.5.

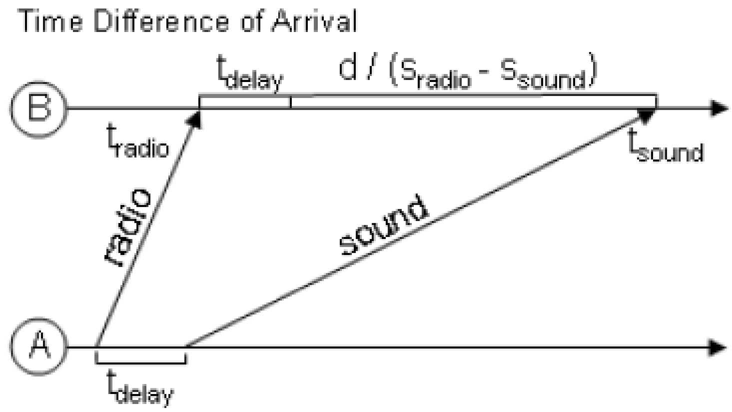

Fig. 2.5 Time Difference of Arrival (TDoA) illustrated [19].

Localization is achieved through an estimation through a method to measure the communication between two nodes (a localized and unlocalized node), after that is could be possible to determine the geometrical placement of each node or position. In other words, the location of target node is determined by special mathematical analysis to measure the distance and angle between nodes.

Currently there are certain localization techniques which are widely used in WSN, such as the following.

(i) Lateration occurs when distance between nodes is measured to estimate location.

(ii) Angulation occurs when angle between nodes is measured to estimate location.

(iii) Trilateration. Location of node is estimated through distance measurement from three nodes. In this concept, intersection of three circles is calculated, which gives a single point which is a position of unlocalized node.

(iv) Multilateration. In this concept, more than three nodes are used in location estimation.

Triangulation is the most used mechanism, where at least two angles of an unlocalized node from two localized nodes are measured to estimate the position of target node [1].

All of the methods above are absolute localization ones because the ground truth position or global coordinate in a specific environment is acquired. Another kind of localization estimation is called relative localization, in which all devices in the network, regardless of their absolute coordinate knowledge, estimate the range between themselves and their neighboring devices. An absolute localization can be transformed into a relative localization—relative to a second reference point, that is. However, a second absolute localization is not always available [7].

The localization method in some special scenarios [32] and the anther introduce the evaluation criteria for localization in WSN which is shown in Figure 2.6.

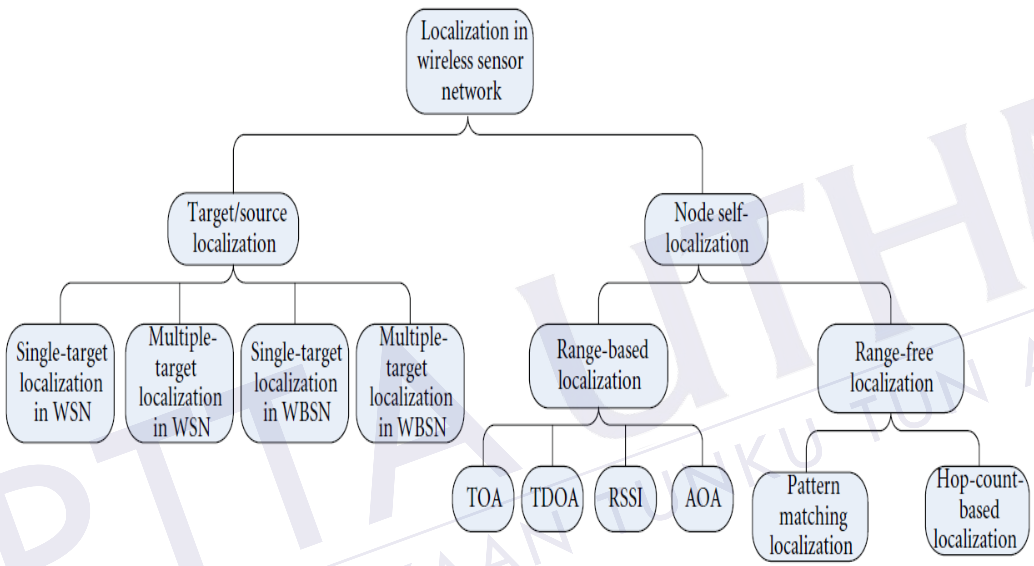

Figure 2.6: Taxonomy of Localization Methods.

The issues of sensor localization, objects localization and their movement tracking in wireless sensor networks [53]. We identified the challenges of these problems, proposed algorithms, and quantified their superior performance with simulations. There were inherent connections between the issues of sensor localization and the techniques of data dimensionality. The developed a centralized sensor localization algorithm, a distributed sensor localization algorithm and a robust sensor localization algorithm. In ender to overcome these challenges, the distributed algorithms to locating the boundary of continuous objects in the coverage of a sensor network. proposed thsoe difficulties and enable efficient tracking in real-time fashion. Propose a distributed on demand localization method based on the above position estimation method with any anchor sensors. Without loss of generality, one sensor's position is needed to be estimated. The sensor (starting sensor) first initializes flooding to pass its message to three or more anchor sensors, which are called ending anchors. The ending anchors send their locations and the flooding routes as shown in Figure 2.7.

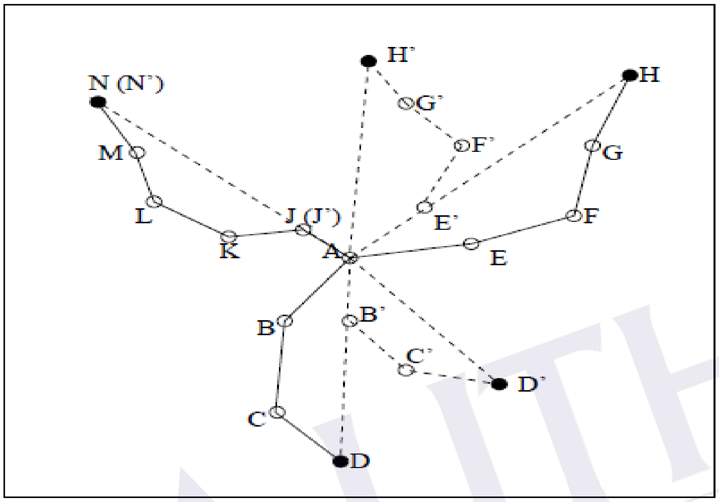

Fig. 2.7: Position estimation in the adjacent area of a sensor without position known.

Then, the starting sensor knows the positions of ending anchors and routes to each of them. The starting sensor first simply estimates its physical position with a trilateration based on its hop distances to ending anchors, which is similar to the distance vector exchange based method [11]. Then, it estimates the positions of those sensors that are on these routes and one hop away from it. Figure 2.7 illustrates the procedure: A is the starting sensor, D , H, and N are the ending anchors. A knows the positions of D, H, and N as well as the routes to them, which are (A,B,C,D), (A,E, F, G,H), (A, J,K,L,M,N), respectively. A estimates that the position of B is B′ on dashed line AD, the position of E is E′ on dashed line AH, and the position of J is J′ on dashed line AN [53].

The Self Positioning Algorithm (SPA), which is used in distributed mobile wireless networks without GPS receivers was proposed first by. In every node establishes its local coordinate system by setting itself as the origin [30]. Two other nodes are randomly chosen under the condition that the three nodes do not lie on the same line and can communicate with each other. Then, any other node can be localized if the distance to each of the three nodes can be estimated. After choosing the group of nodes having the highest density in the network as the localization reference coordinate system, the other local coordinate systems can be adjusted to build the global coordinate system by coordinate transformation. The disadvantage of SPA is that the communication cost and convergence time grow exponentially with the number of nodes since each node participates individually in the process of building and merging the local coordinate system [18].

Based on the above, localization schemes are classified according to the following:

- Anchor based
- Anchor free
- GPS based
- GPS free
- Range based
- Range free
- Centralized
- Stationary or mobile sensor nodes
- Distributed
- Fine grained
- Coarse grained

In this study, the focus will be on GPS-Free localization technique. Te next chapter describe this technique.

2.5 GPS- FREE AND GPS-BASED LOCALIZATION SCHEMS

GPS-based schemes are costly and can't be used in small projects because GPS receiver is expensive and must be fixed on every node without exemption. Therefore, with a wide area and many node required, GPS-based schemes is not a good solution in this case. But in GPS-based schemes localization accuracy is very high, and this is the main factor for using this scheme in state of the art purposes and military applications. However, a GPS-free algorithms never depend on GPS receivers to locate the unlocalized node, the main technique here is to calculate the distance between the nodes according to local network, and because of that GPS-free schemes are less costly but accuracy is less comparing to GPS-based schemes [13]. Another important issue in GPS-free localization algorithms is the fundamental performance impact of different parameters. In particular, a set of parameter-setting guidelines for the proposed algorithm is established by making use of a probability approach. A simulation analysis on a specific numerical example is conducted to validate the mathematical analytical results of the proposed parameter-setting guidelines [29].

Another issue with GPS-based localization is the GPS is not always available because of the line of sight conditions. For instance, it does not work indoors, under water, or in a subway. Secondly, since a typical GPS receiver costs approximately one hundred dollars, it is too expensive to equip each sensor with a GPS receiver, considering that these sensors are usually designed to be low cost and disposable [53].

Finally, the GPS receivers are highly power-consuming while the sensors are designed to require low-power and therefore to ensure their greater longevity. Based on the previous discussion, alternative sensor localization systems are required. Considering the application scenarios of sensor networks, designing localization systems for sensor networks is more challenging than designing localization systems for applications in many other domains.

Most of the current literature on location discovery in WSNs assumes the availability of GPS receivers at some nodes or beacon nodes with known position. Their locations are then used to determine the positions of other ordinary sensor nodes, which do not have GPS receivers. Having a GPS receiver at sensor nodes may not be feasible due to the limitations of satellite coverage or obstructions in the path of satellite signals or harsh climate conditions [42], [51],[55].

Proposes GPS-free localization [15]. He argues that highly accurate TOA is acquired by means of measuring the time difference between two simultaneously transmitted radio and ultrasonic signals at the receiver. With the assistant of coarse AOA information, the flip ambiguity is fixed. The Coordination system in GPS-FREE localization once the local coordinate systems have been constructed at the master nodes, all but one of the local coordinate systems needs to reorient their system in order for the network to converge to a single global coordinate system. The, merging of two local coordinate systems is the process of one coordinate system coinciding with another using affine transformations including translation, reflection, rotation around any center, shearing and scaling as shown in Figure 2.8 [29].

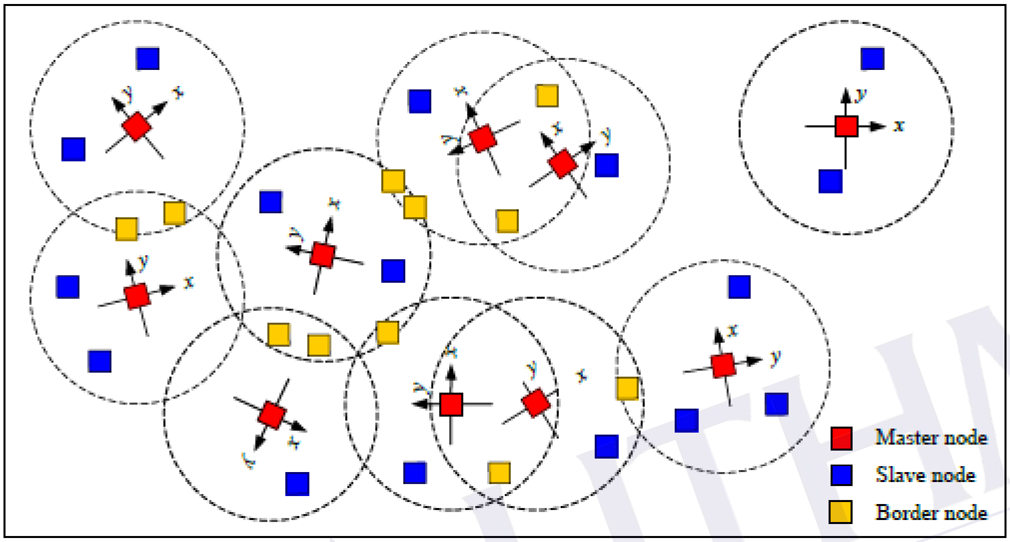

Figure 2.8: Wireless sensor network after the local coordinate system is established [29].

In the global coordinate system organization phase, the coordinates of border nodes are determined by at least two neighbor nodes when there exists a master-slave relationship between the master nodes of two local coordinate systems. Because GPS-Free localization scheme has any anchor. The first step is to find a local relative position estimate, or the initial coordinate system. We use triangulation techniques. First of all, we find a triangle with maximum area among all the ones in the map made up with the ultrasonic connection as the initial anchors as shown in Figure 2.9.

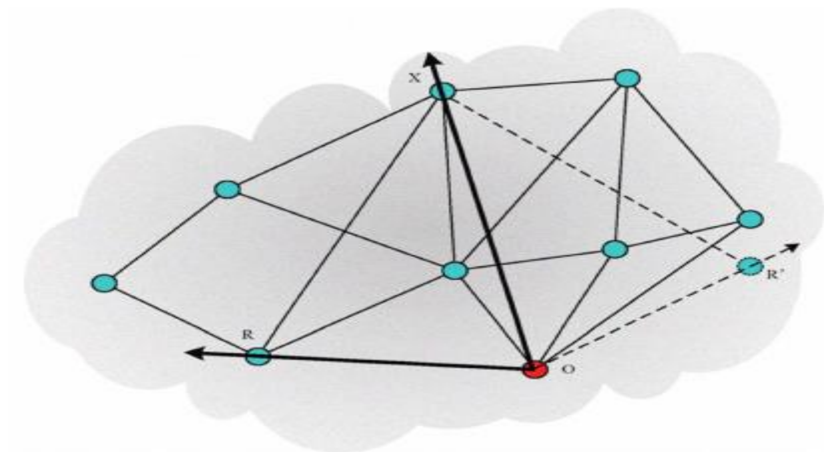

Figure 2.9: Construction of initial coordinate system

The node with the minimum id on the comer of this triangle assumes itself at the origin of the initial coordinate system and the node with lager id is selected to form the positive x-axis [29].

2.6 GPS-FREE LOCALIZATION ALGORITHMS

The technical foundations of today's localization techniques and present the tradeoffs inherent in algorithm design. No specific algorithm is a clear favorite across the spectrum. For example, some algorithms rely on prepositioned nodes, while others are able to do without. Other algorithms require expensive hardware capabilities. Some algorithms need a way of performing off-line computation, while other algorithms are able to do all their calculations on the sensor nodes themselves.

Localization is still a new and exciting field, with new algorithms, hardware, and applications being developed at a feverish pace; it is hard to say what techniques and hardware will be prevalent in the end.

The development of localization algorithms is proceeding at a fast pace. While the task appears simple, to compute positions for each node in a sensor network, the best algorithm depends heavily on a variety of factors such as application needs and available localization hardware. Future algorithms will address new sensor network needs such as mobile nodes and ultra-scale sizes. For example, [29] designed a GPS-free localization algorithm in WSNs called the Matrix transform-based Self Positioning Algorithm

(MSPA), where the task is to use the distance information between nodes to determine the coordinates of static nodes in a 2D or 3D space. At the heart of the approach is the matrix transform technology and a totally distributed network structure is adopted. Similar to other relative localization algorithms, the coordinate establishment phase is split into two phases: the establishment of local coordinates at a subset of the nodes and the convergence of the individual coordinate systems to form a global coordinate system. Obviously, their approach is a range-based relative localization algorithm applied in a stationary sensor network. They propose an improved versions of DVHop algorithm as QDV-Hop algorithm and UDV-Hop algorithm for better localization without the need for additional range measurement hardware. Their proposed algorithm focuses on third step of DV-Hop, first error terms from estimated distances between unknown node and anchor nodes is separated and then minimized. In the QDV-Hop algorithm, quadratic programming is used to minimize the error to obtain better localization. However, quadratic programming requires a special optimization tool box that increases computational complexity.

Rather than use globally accessible beacons or expensive GPS to localize each sensor, in GPS-free localization some algorithms are centralized while others are distributed. The summary of proposals for Localization in WSN is shown in Table 2.1.

Table 2.1: Summary of proposals for Localization in WSN

Author/s	GPS-Free Algorithm	Accuracy	Cost
Wylie an J. Holtzman (1996)	The scholars proposed a method based on parameter hypothesis test which determines the measurements whether belong to NLOS by comparing the NLOS variance with the LOS variance	High	Low
Long et al., (2012)	The scholars proposed normalized incremental sub-gradient algorithm to solve the energy-	High	High

	based sensor network source localization problem where the decay factor of the energy decay method is unknown		
Xiang (2004)	The researcher proposes three sensor localization algorithms based on the multidimensional scaling techniques. They include a centralized sensor localization algorithm, a distributed sensor localization algorithm, and a robust sensor location algorithm based on multidimensional scaling. Three differentiated sensor localization methods are also proposed.	High	Low
Guibin et al., (2010)	Argue proposed proposed a GPS-free localization scheme for WSNs that provide the ability to compute correct coordinates under a wider variety of conditions and its robustness to measurement errors. Their algorithm includes four steps: the construction of an initial coordinate system, iterative multi-lateration, mass-spring optimization, and last, the coordinate system rotation.	High	High

Nabil et al., (2013)	The authors recommend Range-based schemes are distance-estimation and angle-estimation-based techniques. Important techniques used in range-based localization are received signal strength indication (RSSI), angle of arrival (AOA), time difference of arrival (TDOA), and time of arrival (TOA)	High	Low
Huang et al., (2006)	Proposed range-free methods are distance vector (DV) hop, hop terrain, centroid system, APIT, and gradient algorithm. Range-free methods use radio connectivity to communicate between nodes to infer their location. In range-free schemes,distance measurement, angle of arrival, and special hardware are not used	Low	Low
Manzoor (2010)	Proposes APIT (Approximate Point In Triangulation) scheme, anchor nodes get location information from GPS or transmitters. Unlocalized node gets location information from overlapping triangles. The area is divided into overlapping triangles. In APIT, the following four steps are	High	Low

	included: (i) Unlocalized nodes maintain table after receiving beacon messages from anchor nodes. The table contains information of anchor ID, location, and signal strength. (ii) Unlocalized nodes select any three anchor nodes from area and check whether they are in triangle form. This test is called PIT (point in triangulation) test. (iii) PIT test continue until accuracy of unlocalized node Location is found by combination of any three anchor nodes. (iv) At the end, center of gravity (COG) is calculated.		
Jonathan and Christopher (2008)	Propose a centralized localization algorithm. Allows an algorithm to undertake much more complex mathematics than is possible in a distributed setting. They uses MDS-MAP is a centralized algorithm Instead of using semi-definite programming, however, MDS-MAP uses a technique from mathematical psychology called	High	Low

	multidimensional scaling (MDS).		
Lei and Qingzheng ((2010)	The scholars present a GPS-free localization scheme for node localization in WSNs called the Matrix transform-based Self Positioning Algorithm (MSPA), where the task is to use the distance information between nodes to determine the coordinates of static nodes in a 2D or 3D space. At the heart of the approach is the matrix transform technology and a totally distributed network structure is adopted. Similar to other relative localization algorithms.	Low	Low
Shang and Ruml (2003)	The scholars present a centralized algorithm called MDS-MAP which basically consists of three steps: **1**. First the scheme Computes shortest paths between all pairs of nodes in the region of consideration by the use of all pair shortest path algorithm such as Dijkstra's or Floyd's algorithm. **2**. Next the classical MDS is applied to the distance matrix,	High	High

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